

The Solar Probe Mission

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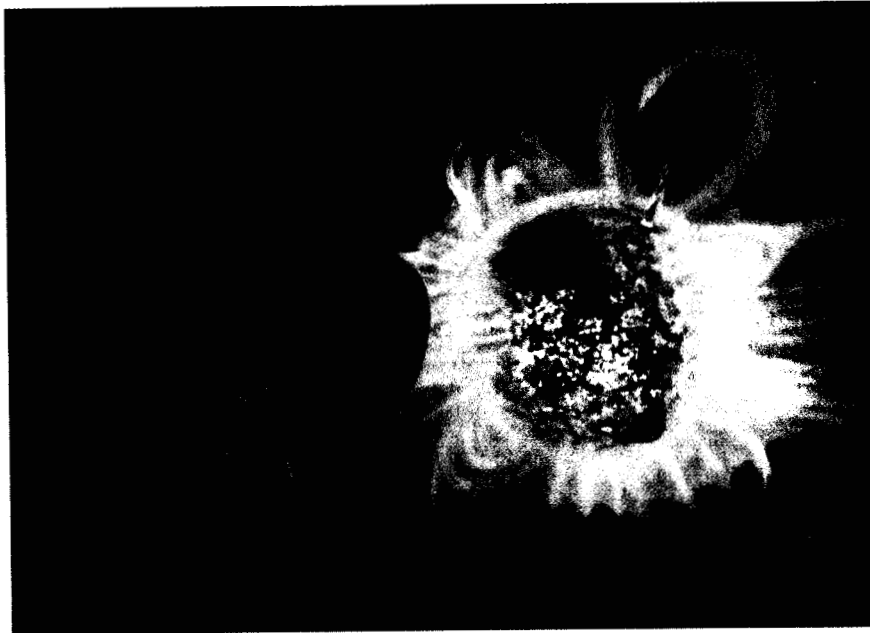
The Solar Probe mission is now part of the Outer Planets/Solar Probe NASA line and Solar Probe will be launched in 2007. Initial instrument development research, supported by a NASA NRA, has shown that the measurements requirements can be accomplished with a low-mass, low-power core payload. In addition, conjunction experiments with the NEAR and MGS spacecraft show promise for high telemetry rates at perihelion to enhance data return. An AO for instruments has been issued by NASA and proposals are due June 6, 2000. The mission design now has two close flybys (one at solar maximum and one at solar minimum) and is based on a radioisotope power source. The mission, scientific objectives, science strawman payload and spacecraft will be discussed. In particular, we will identify some of the new SOHO results and will discuss how Solar Probe will play an essential and unique role in carrying our understanding further.

Interball Kiev 2000 International Symposium
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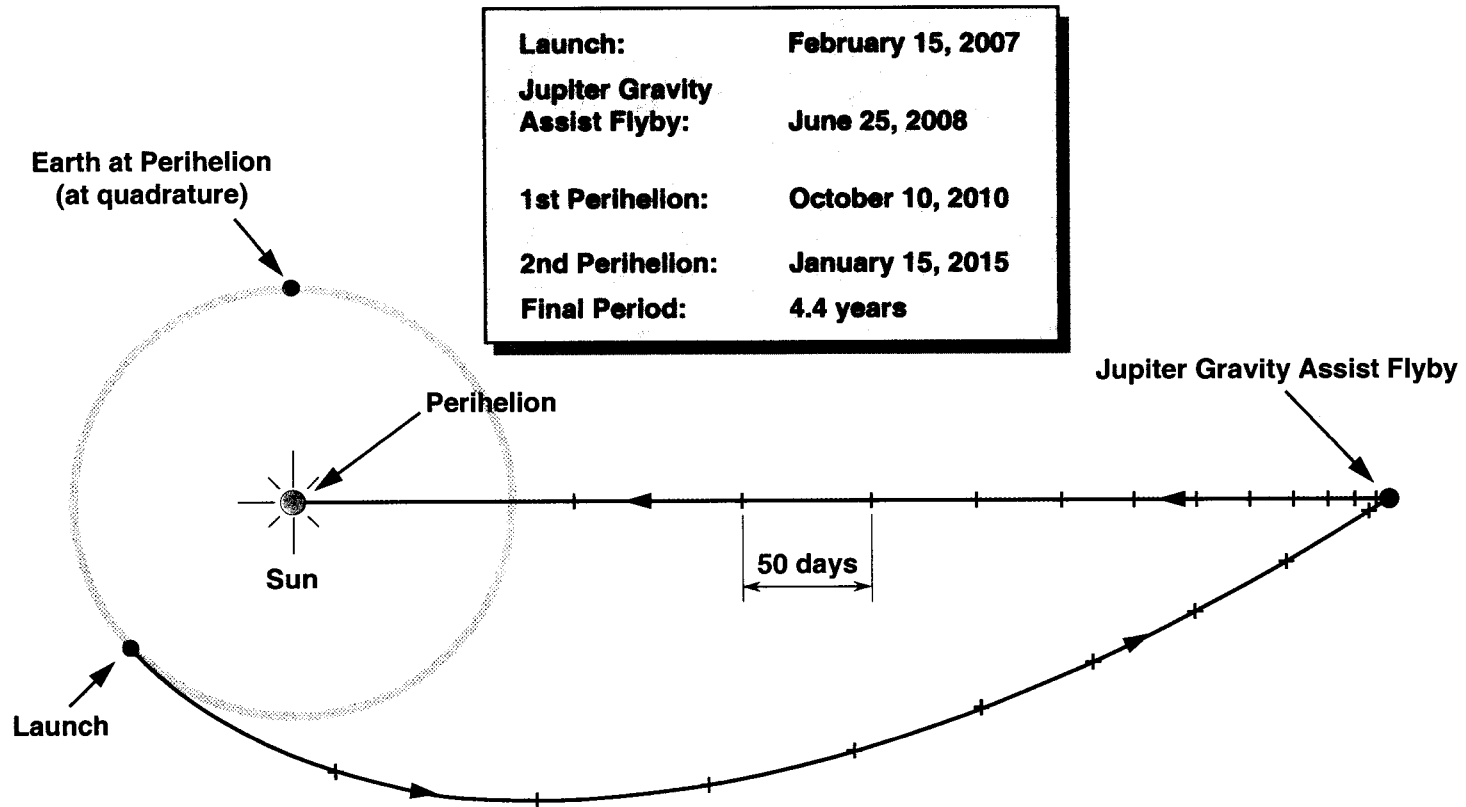
Solar Probe



Science Objectives

- *Determine the acceleration processes and find the source regions of the fast and slow solar wind at maximum and minimum solar activity*
- *Locate the source and trace the flow of energy that heats the corona*
- *Construct the 3-dimensional coronal density configuration from pole to pole, and determine the subsurface flow pattern, the structure of the polar magnetic field, and its relationship with the overlying corona*
- *Identify the acceleration mechanisms and locate the source regions of energetic particles, and determine the role of plasma turbulence in the production of solar wind and energetic particles*

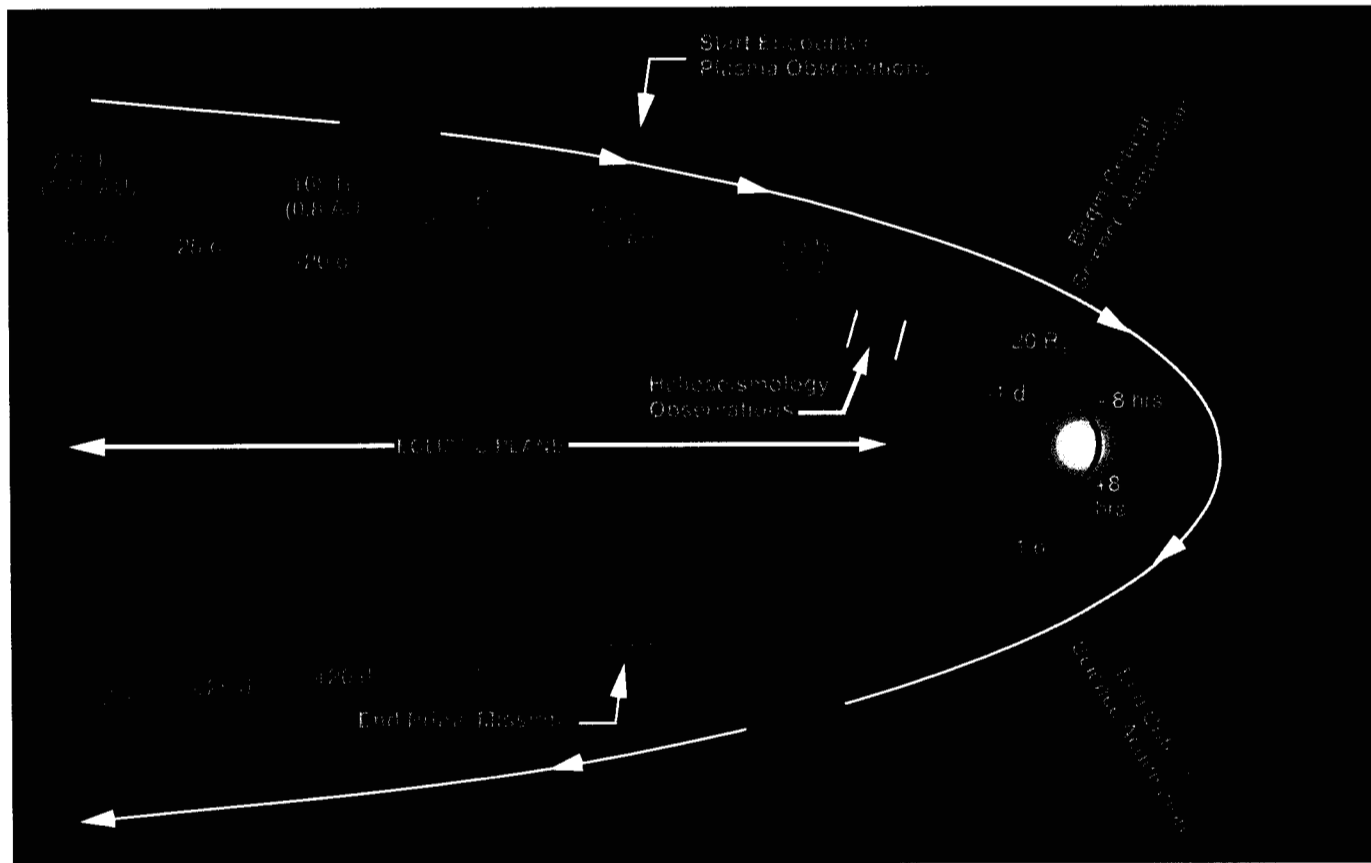
Jupiter Gravity Assist Trajectory



The planned trajectory for Solar Probe will take it from launch at Earth out to Jupiter, where the planet will be used for a gravity assist. This will alter the spacecraft trajectory to a highly elliptical orbit with a perihelion of $4 R_S$ and an aphelion of 5 AU. The mission duration is approximately 3.7 years from launch to first solar perihelion, and up to 8.1 years from launch to second perihelion.

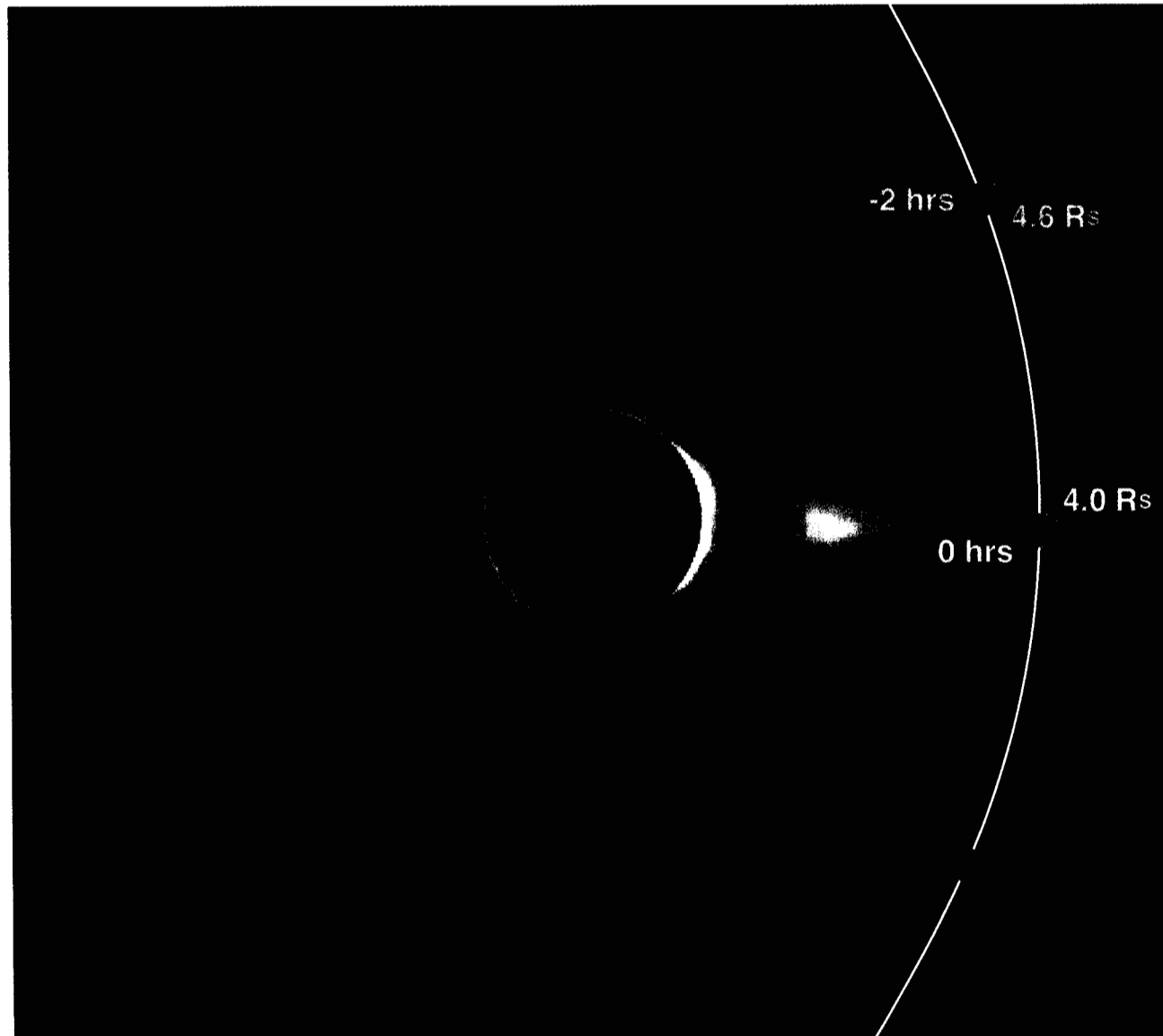
Solar Probe Mission Profile

(view from Earth)

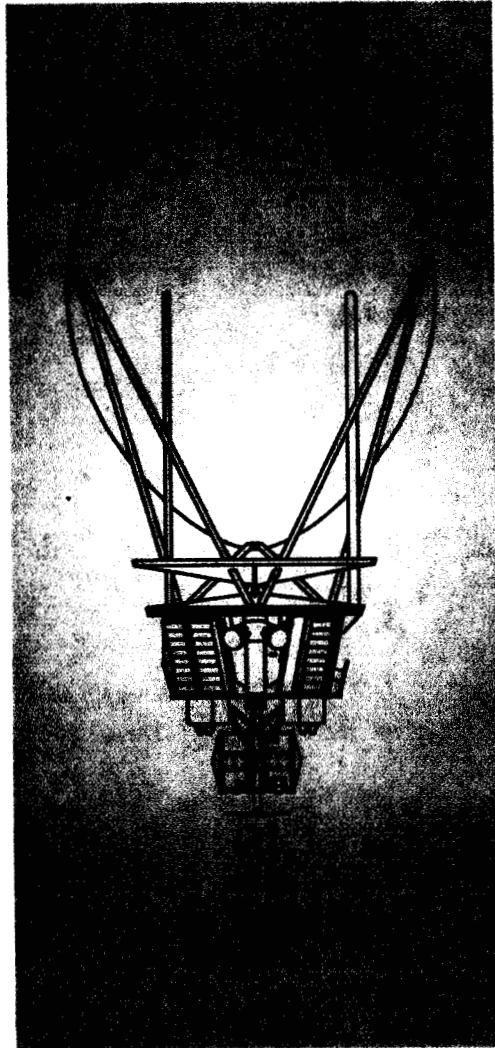


As shown above, encounter measurements will start on approach to the Sun at 10 days prior to perihelion and will continue to 10 days after perihelion. During this time (within 0.5 AU), the inner heliosphere and the corona will be observed in-situ for the first time. Helioseismology measurements will begin at 4 days before perihelion (0.2 AU). The most intense observation period will take place during the two days centered on closest approach (the critical science acquisition period indicated in the figure).

***Solar Probe trajectory and orientation
near perigee, as viewed from Earth***



Solar Probe Science Payload



Remote Sensing Instruments

Visible Magnetograph/Helioseismograph

EUV Imager

All-sky, 3-D Coronagraph Imager

In-situ Instruments

Magnetometer (with boom cables)

Solar Wind Ion Composition and Electron Spectrometer

Energetic Particle Composition Spectrometer

Plasma Wave Sensor (with boom cables)

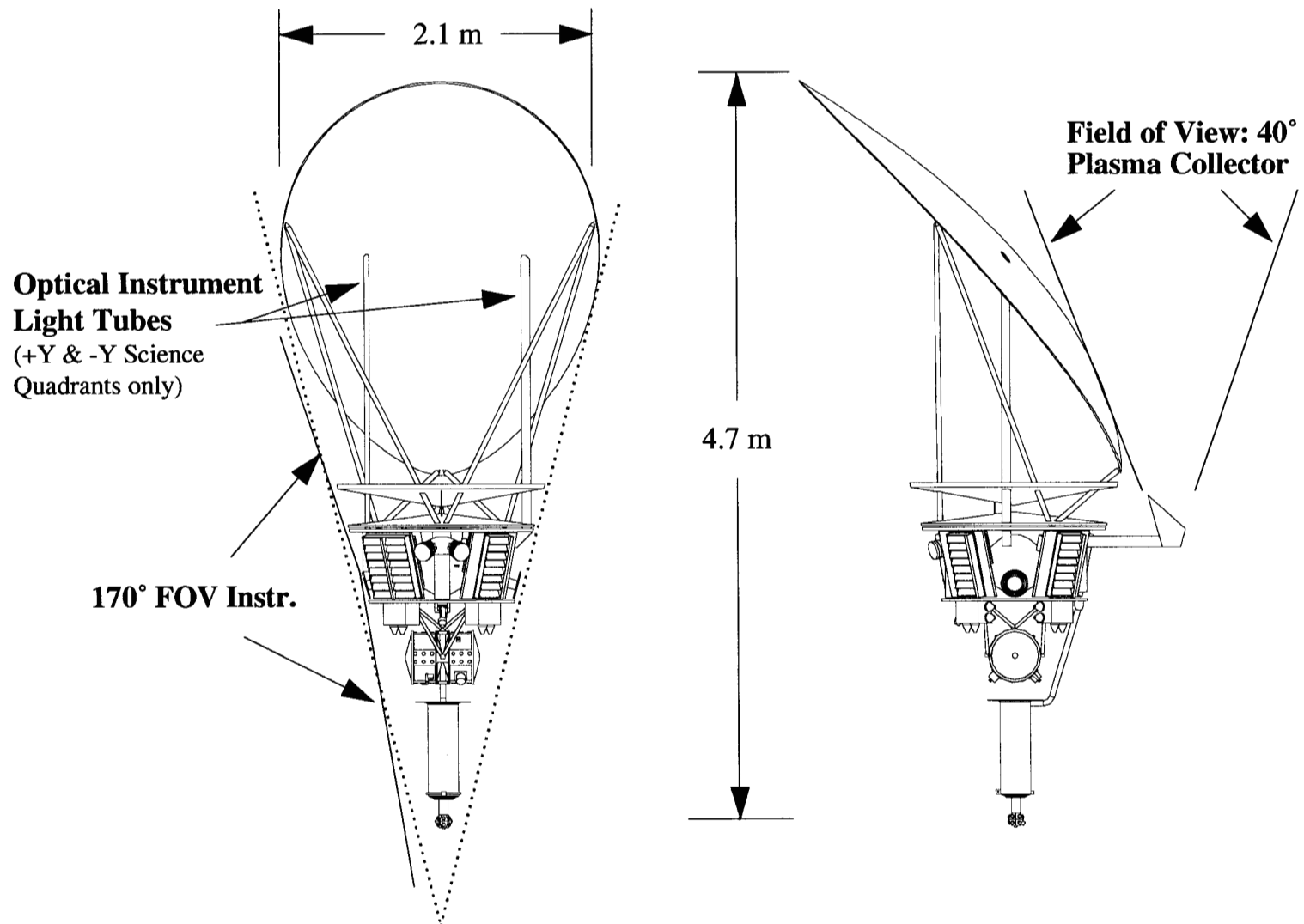
Fast Solar Wind Ion Detector

Total

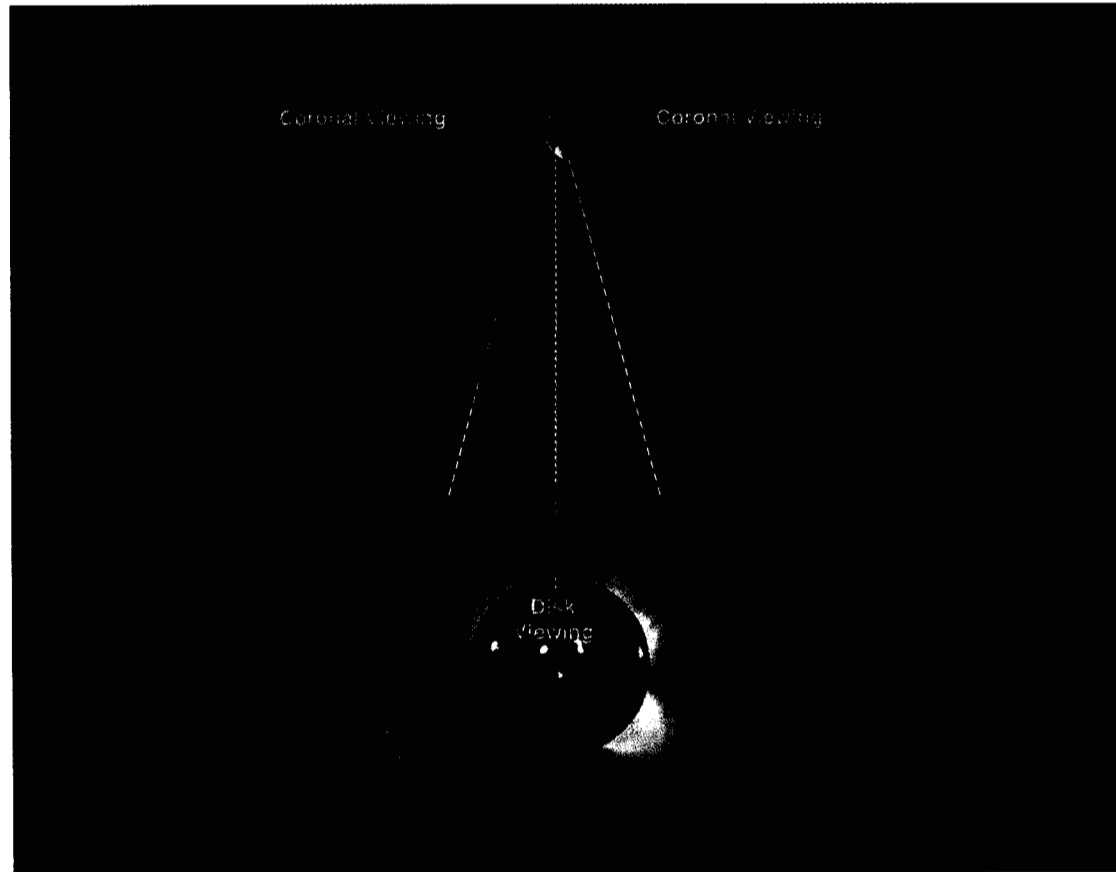
21 kg

15 W

Solar Probe Baseline Configuration

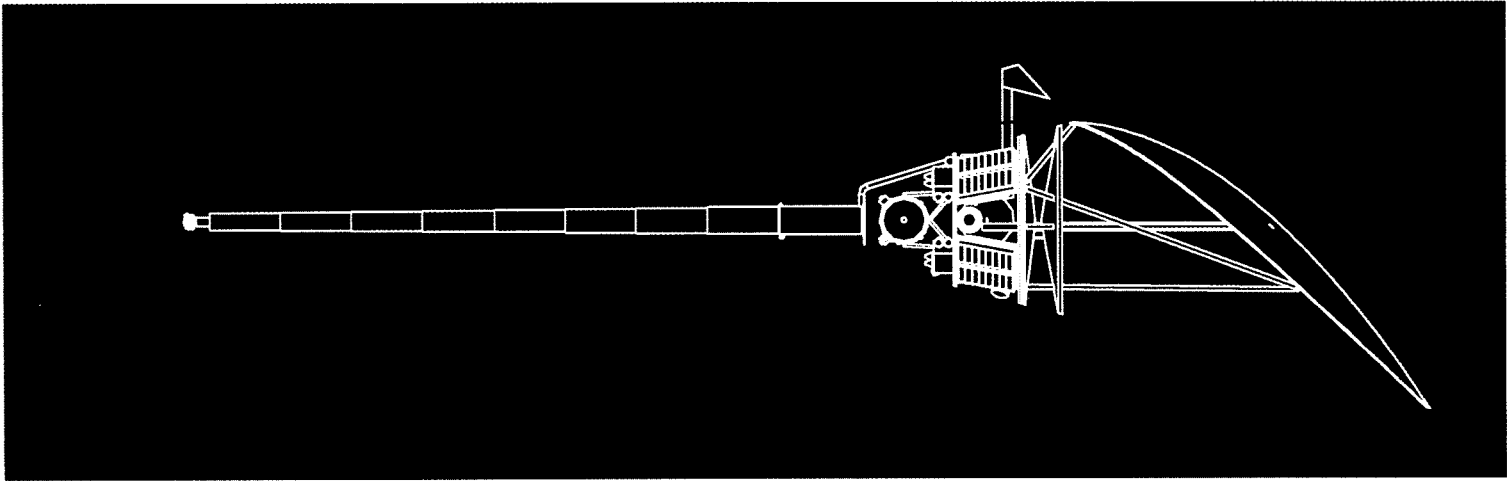


Solar Probe Corona/Disk (Pole) Viewing

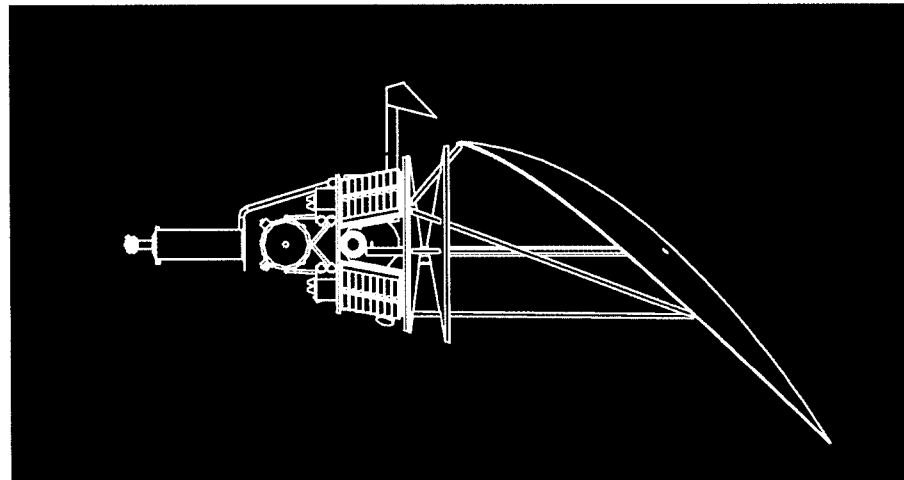


The coronagraph on Solar Probe will use the heat shield as a solar disk occulter and will be able to see from fairly close to the solar surface to the antisolar direction. It will have, essentially, a 4π steradian field of view (except for the area obstructed by the heat shield). One important feature of the coronagraph viewing is the ability to look in the forward and backward directions to see what kind of coronal structures the spacecraft is moving through. In particular, over the polar regions it will be going into and out of polar plumes. There will be simultaneous high-resolution (10^{-2} s) field plasma, and plasma wave measurements which will tell us a great deal about the microstructure of polar plumes. The overall coronagraph images will allow 3-D tomography of coronal structures.

Solar Probe's Extendable Boom



As Solar Probe approaches the Sun, the science boom (boom science instruments yet to be determined) will be retracted into the spacecraft's umbra region. In the figure above, the science boom is shown in the fully extended position, at $10 R_S$ and beyond. The figure on the right shows the boom fully retracted, at $4 R_S$.



Carbon-Carbon Heat Shield Material



***BTT/JKA
January 14, 2000***

Heat Shield Mass Loss Rates

- 1981 design mass loss rate of 2.5 mg/s would lead to a spacecraft potential of less than 20 volts
- New Lockheed-Martin/General Atomic tests indicate the mass loss rate will be substantially less

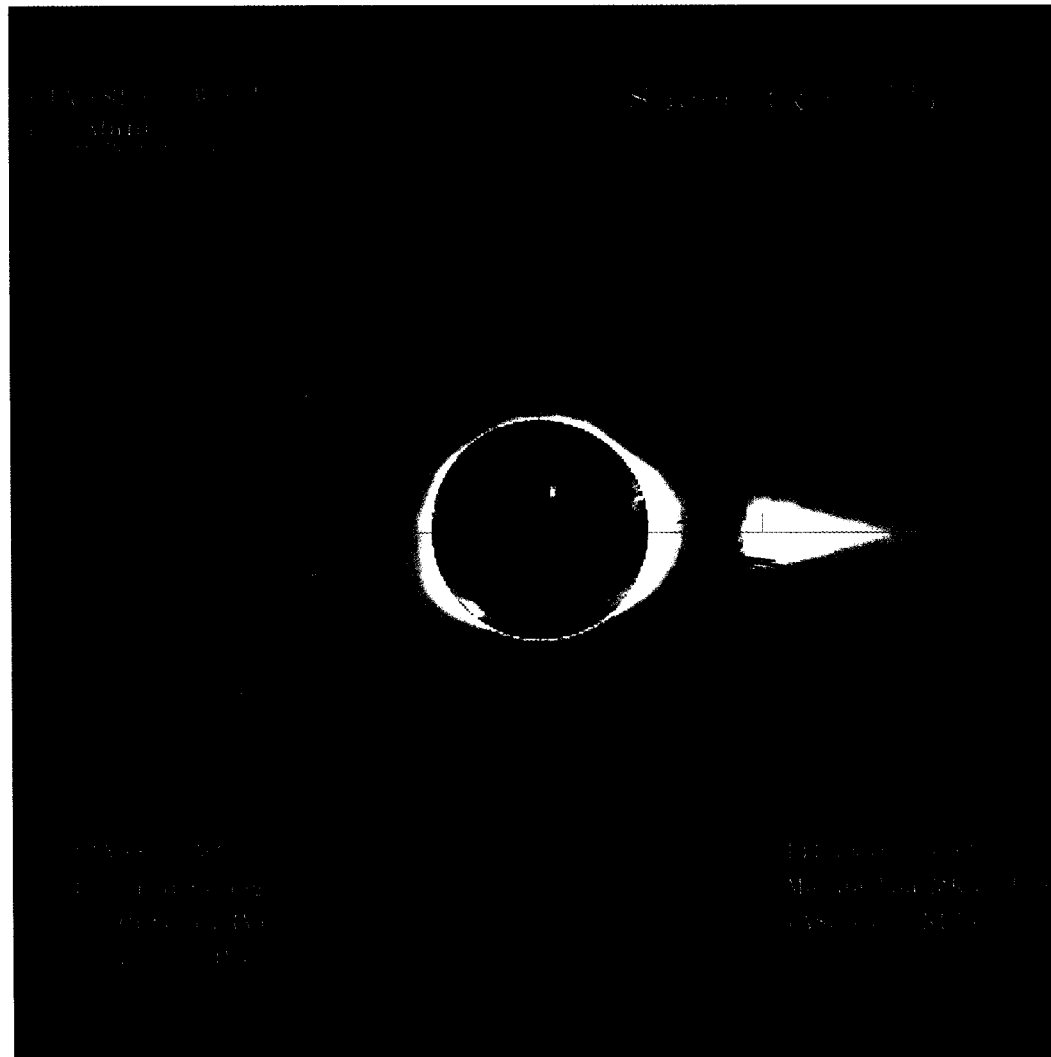
$$2.1 \times 10^{-3} \text{ mg/s} \quad C_1$$

$$0.6 \times 10^{-3} \text{ mg/s} \quad C_2$$

$$0.7 \times 10^{-3} \text{ mg/s} \quad C_3$$

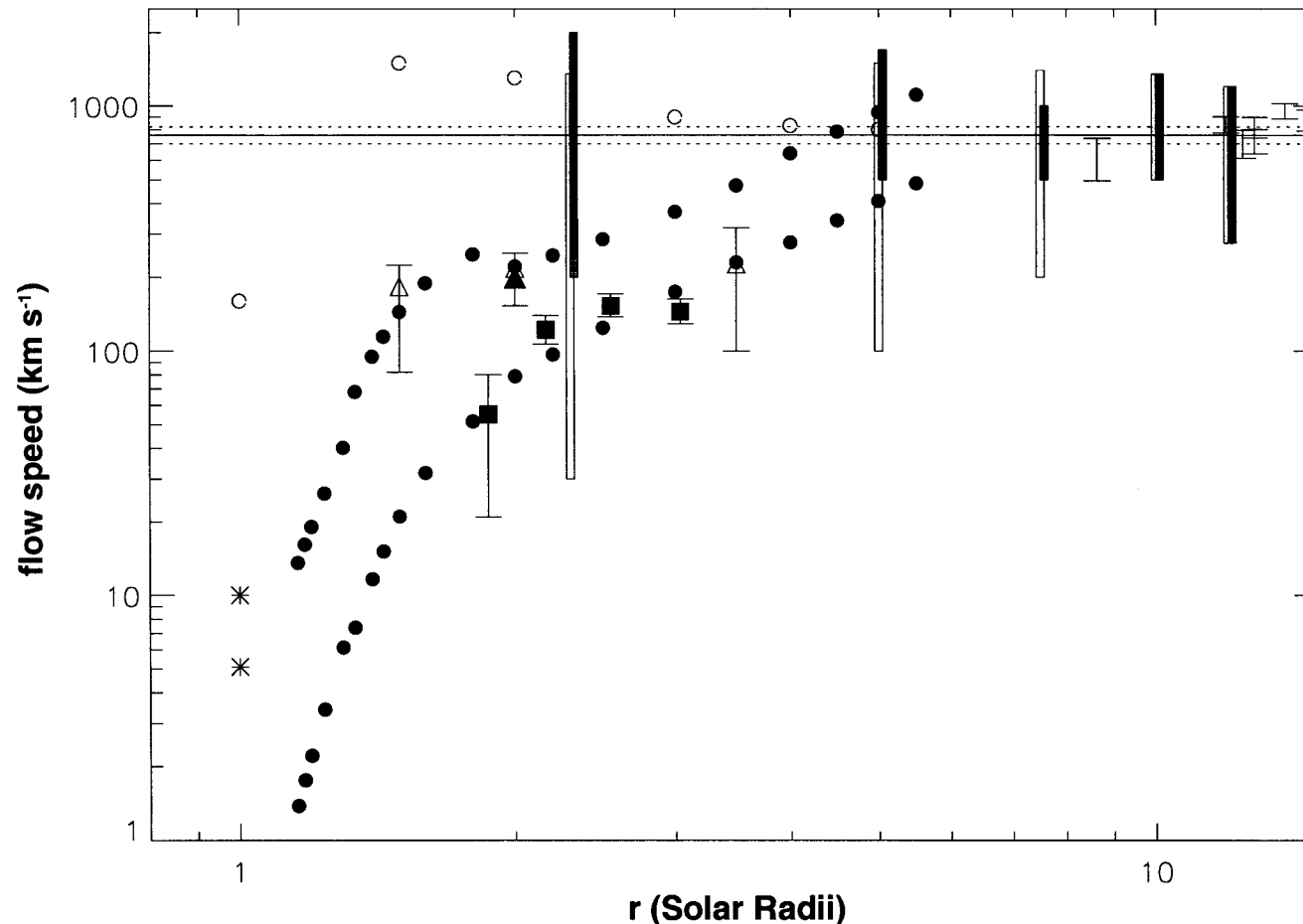
$$3.4 \times 10^{-3} \text{ mg/s} \quad C_1 + C_2 + C_3$$

Ulysses Solar Wind Speed Observations



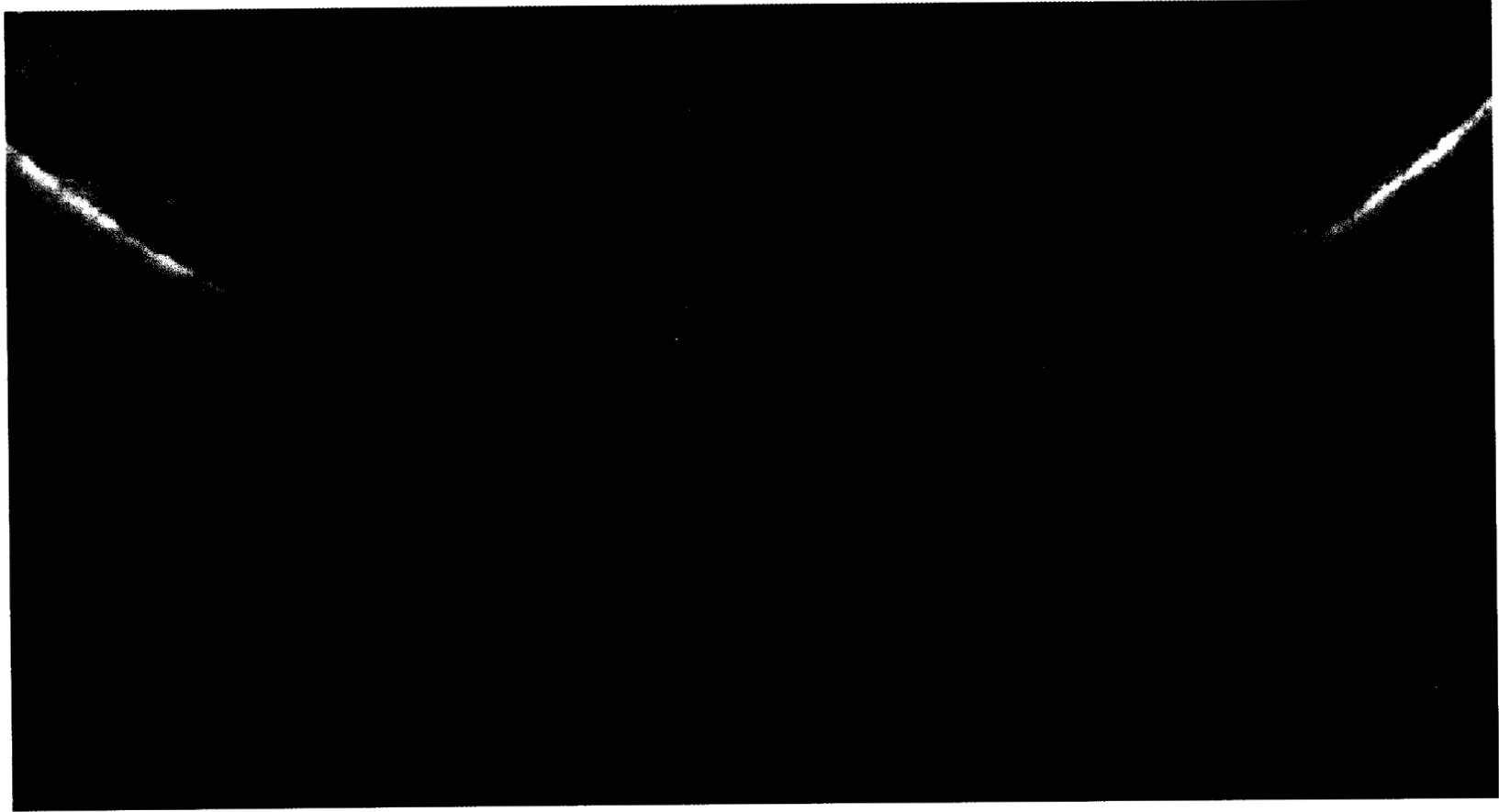
Measurements of the solar wind from the Ulysses mission show that solar wind velocities are 750-800 km/s over the Sun's polar regions and about 400 km/s over the equatorial regions (slow solar wind region). There are spatial variations in the latter region because Ulysses was moving into and out of high speed streams.

Solar Wind Speed vs. Distance



This plot shows the flow speed above polar coronal holes and indicates that the solar wind acceleration is relatively rapid, reaching velocities of the terminal speeds of about 800 km/s by a distance of 10 R_S . SOHO measurements have placed the velocities on the order of 100 to 150 km/s as maximal, at a distance of 2 to 3 R_S . Solar Probe will cross the polar regions at 7 R_S and if the coronal holes extend down to 30 degrees latitude at the time of its passage, it will extend the distance of Solar Probe down to 5 R_S in the high-speed region.

Polar Plumes



This image from the Extreme-ultraviolet Imaging Telescope (EIT) on the Solar and Heliospheric Observatory (SOHO), taken March 7, 1996, shows the area around the solar south pole. The dark regions indicate the coronal hole region, with the plumes extending radially outward. Results from SOHO indicate that the plumes are about 2 to 3 degrees in width and can extend out to 30 R_S . They can be clearly seen out to at least 15 R_S . Experiments to determine the longevity of polar plumes have indicated that they have lifetimes of at least a couple of days.

SOHO and Ulysses Results: New Questions

Polar Plumes/High Speed Solar Wind

- Polar plumes are located throughout polar coronal holes, have density enhancements of up to 30% relative to interplume regions, extend from the photosphere to at least $30 R_S$, are stable for at least several days, and are associated with intense monopolar fields at the photosphere.
 - What are these structures and how are they maintained?
 - There is no theoretical model that can explain the small spreading with radial distance.
 - The fundamental question of the acceleration mechanism of the high-speed solar wind still remains, but it is slightly revised: Does it come from plume or interplume regions?

Slow Speed Solar Wind

- The slow solar wind has a constant acceleration from 3 to at least 30 R_S . (SOHO result)
 - What mechanism can explain such observations?
 - Are the heating and acceleration mechanisms different than for high speed streams?

Helioseismology/Circumpolar Jets

- Although SOHO helioseismology measurements in the polar regions are limited, circumpolar jet streams are found within 15 degrees of the pole. The streams extend to only 20,000 km below the visible surface. There is some indication that a polar vortex extends to the bottom of the convection zone.